

**U.S. GENERAL AVIATION:
THE INGREDIENTS FOR A RENAISSANCE**

A Vision and Technology Strategy

for

U.S. Industry

NASA

FAA

Universities

January, 1993

N94- 25097

**U.S. GENERAL AVIATION:
THE INGREDIENTS FOR A RENAISSANCE**

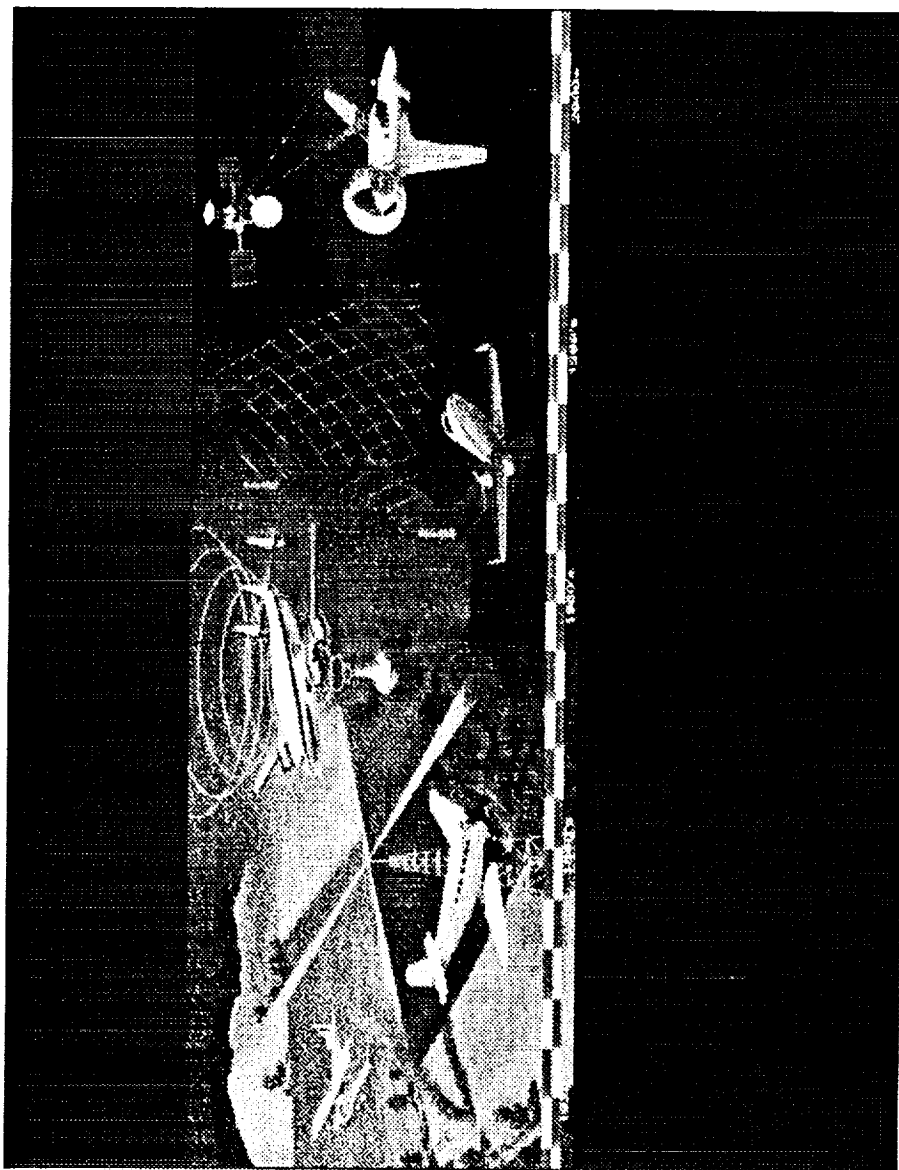
A Vision and Technology Strategy

**for
U.S. Industry
NASA
FAA
Universities**

January, 1993

Title

- In the Nation today, General Aviation
 - Is a **vital** component in the nation's air transportation system
 - Is **threatened** for survival
 - Has enormous **potential** for expansion in utility and use
- This potential for expansion is fueled by **new** satellite navigation and communication, small computers, flat panel displays, and **advanced** aerodynamics, materials and manufacturing methods, and propulsion technologies which create opportunities for new levels of environmental and economic acceptability.
- Expanded general aviation utility and use could have a large **impact** on the nation's jobs, commerce, industry, airspace capacity, trade balance, and quality of life.

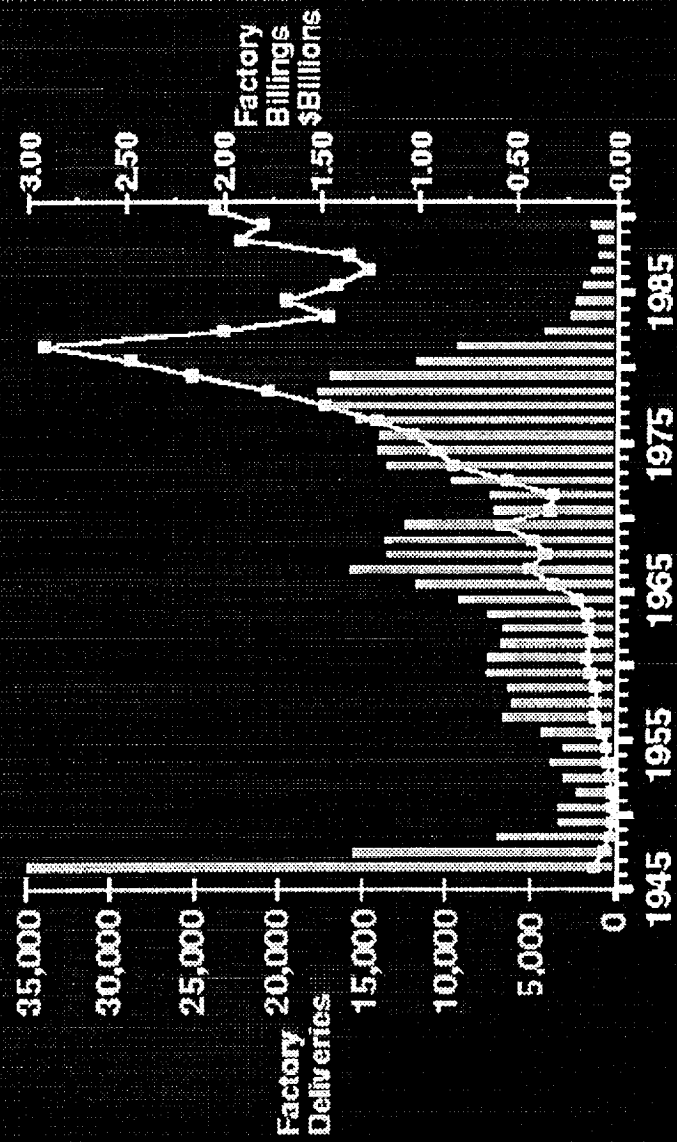


Panorama

- Nation's economic strength and quality of life depend on the **utility, capacity, safety, and efficiency** of transportation and communications systems.
- In the U.S., **Three waves of expansion** have occurred in transportation and communications. These three waves have fueled the nation's economic growth through the emigration of industries out of the cities, into the country.
 1. The first wave occurred earlier than aviation, with the development of canals, rural electrification, and railroads;
 2. The second wave occurred in the 1950's with the development of the Interstate Highways and Hub/Spoke air travel, as well as nation-wide telecommunications;
 3. We are in the beginnings of the third wave, with the implementation of Fiber-optics, satellite communications and navigation, and new air and ground transportation modes
 - On the **ground**, new high-speed and light rail will serve a few hub cities; we could see the introduction of Intelligent Vehicle/Highway Systems.
 - In the **air**, we will see a new generation of supersonic transport airplanes for transoceanic travel; very large (600 to 800 passenger) subsonic jet transports; fast commuter aircraft (perhaps including tilt-rotors); and, potentially, expanded general aviation to more completely serve the "off-airways" population in the nation.

I want to leave you today with an vision of how expanded general aviation transportation could **contribute** to the nation's future transportation infrastructure, **why now** is the time for action; and **how** we can make it happen

GENERAL AVIATION SHIPMENT AND BILLINGS

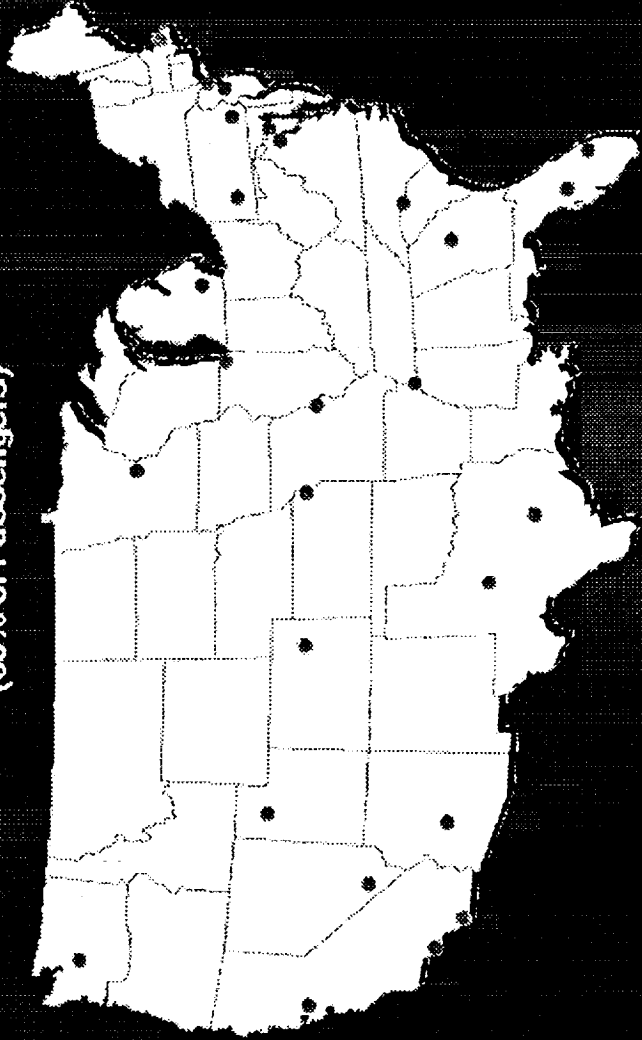


General Aviation Shipment and Billings

- The opportunities facing us are exciting, but the threats are serious:
 - Active **pilots** down 15% in last 10 years
 - Active GA **fleet** contracting, down 10%/10yrs; 3% last year; 75% fly <100 hrs/yr
 - Public use **airports** down 15%/10yrs; 43% **FBOs** operate at loss
 - Aircraft **production** at 3% of 1978 peak; average **age** = 25 years; **technology** > 30 yrs.
 - **Jobs** down over 50% in last 10 years from 43,000 to 20,000 in general aviation
 - **Imports** today = exports of 1978
 - Public **misperceptions** of G.A.'s role in the air transportation system,
 - A broad range of inhibitors to **utility**;
 - The absence of a **national technology strategy** for general aviation.
- Before 1978, GA billings tracked the GNP/GDP. Decoupled in 1978; reasons?:
 - Product Liability
 - Tax code changes
 - GI Bill ended
 - Availability of cheap, used airplanes to satisfy the "enthusiast" market
 - Most important from a technology strategy standpoint, after 1978 we no longer invested in the development of technologies for utility. That is, the lower-end airplanes became out-of-date with the increasingly complex airspace system. In contrast, the higher-end airplanes did keep pace, and they are selling today.

MARKET DEMAND

27 Air Traffic Hubs
(65% of Passengers)

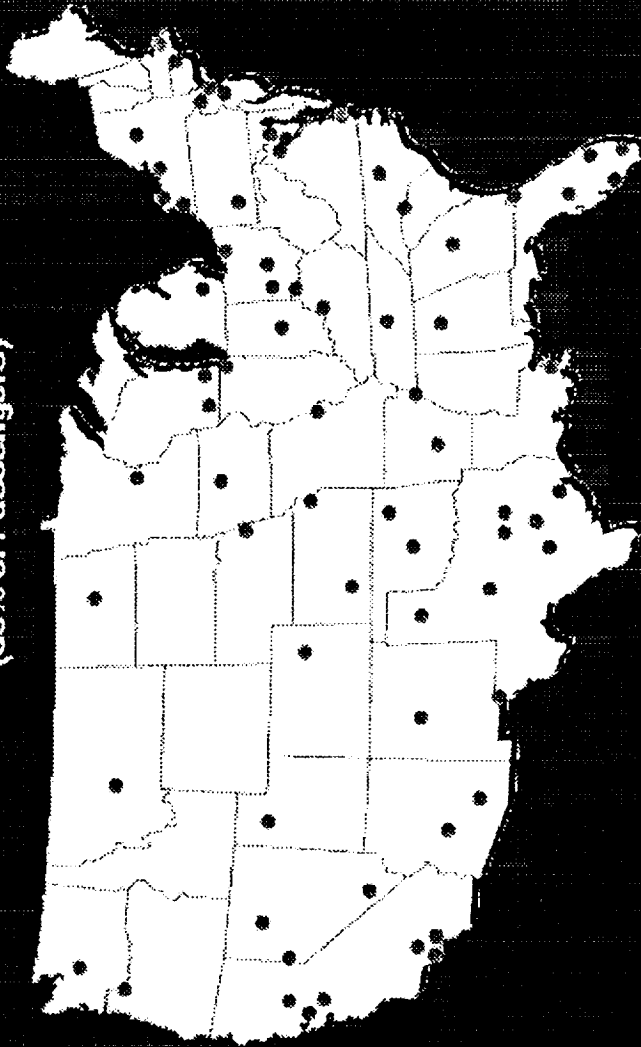


Airport Infrastructure (Hubs)

- The Nation's 27 largest air traffic hubs serve about 65 percent of the total scheduled air carrier passengers.
- These long-haul route hubs are supported by the next level of service:

MARKET DEMAND

Top 71 Large and Medium Hubs
(89% of Passengers)

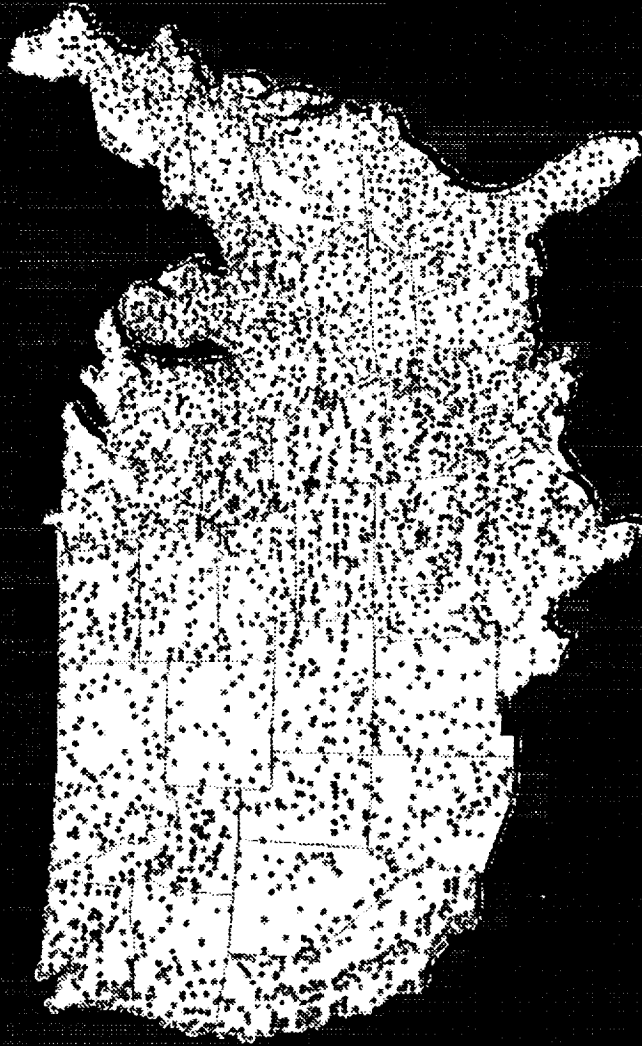


Airport Infrastructure (Hubs + Spokes)

- The top 71 largest and medium hubs serve almost **90%** of the nation's total scheduled air carrier passengers.
- In total, the current hub-spoke system serves **483 cities with 582 airports**. However, this hub-spoke system does not efficiently serve the nation's population which lives further than one-hour's drive from those 582 airports. This part of the nation's population is without scheduled (or even readily available, affordable, non-scheduled) air service, and is therefore out of the country's economic mainstream.
- These data beg the **question**: "How can the nation's air transportation infrastructure be expanded to provide air service to the rest of the population?" This presentation will suggest that the answer lies in general aviation.
- The **good news** is that we already have invested in the ground and air traffic management infrastructure needed to expand air transportation to the rest of the nation:
 - FAA Capital Investment Plan (\$32B) for communications, navigation, surveillance
 - And the rest of the infrastructure consists of the nation's general aviation airport system:

GENERAL AVIATION INFRASTRUCTURE

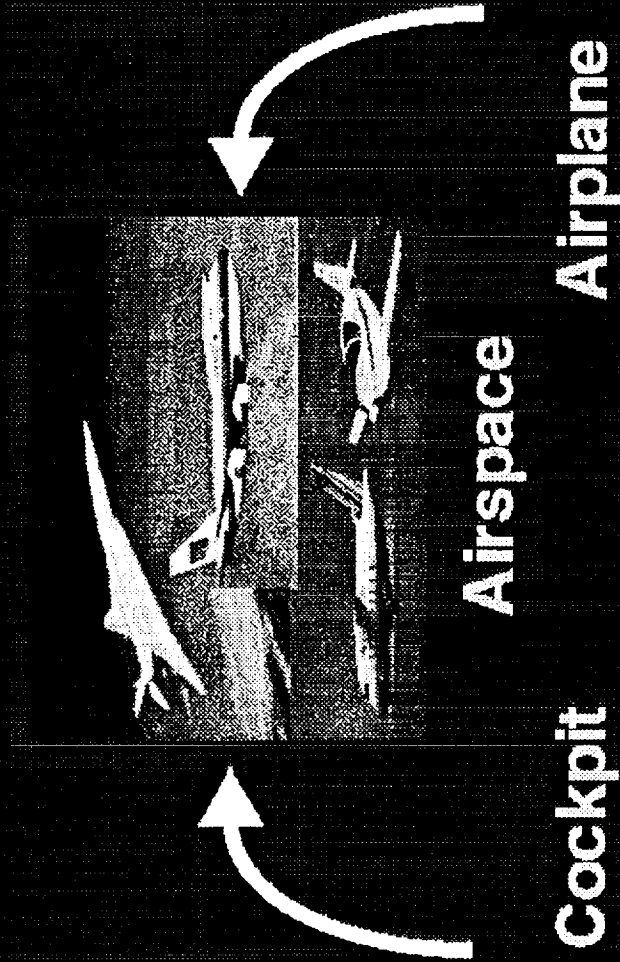
17,000 FACILITIES (5200 PUBLIC-USE)



General Aviation Infrastructure

- This is the **general aviation component** of the nation's air transportation infrastructure
 - Very under-utilized
 - Threatened
 - Need aircraft and airspace systems with higher utility to make full use of this national asset.
- The general aviation airport infrastructure consists of over **17,000 facilities, 13,000 airports, 5200 public-use** airports.
- These airports provide many small and medium industries with transportation to their customers, **rapid, on-demand, random-access transportation** for parts delivery, aerial ambulance services, and organ donor flight support. It is because of the availability of air transportation that these airports help **spread industry and commerce** throughout the nation.
- Even small public-use airports contribute significant **economic benefits**. In **Virginia**, for example, the **average** public-use airport has only 23 aircraft based, and contributes **1.6 million per year** in economic activity, most of which is spent locally.
- What you see here is the rest of the nation's air transportation infrastructure which we already own and which **could be** even more important, economically, in the future.

TECHNOLOGY INGREDIENTS



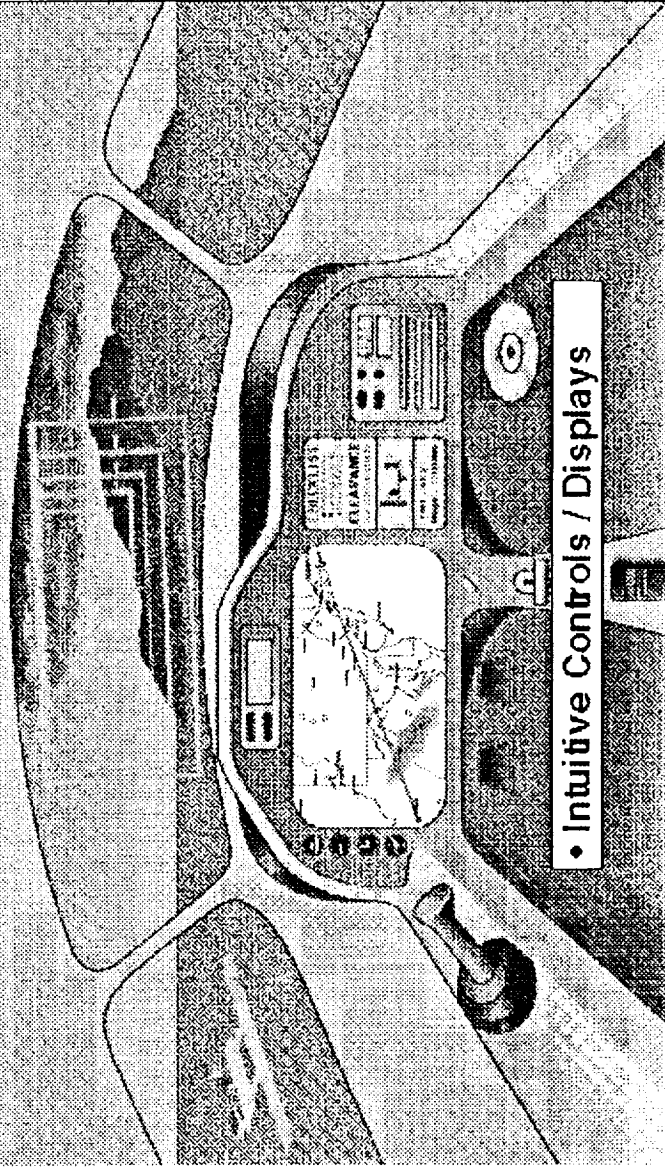
Technology Ingredients

- Let's look at the technology ingredients which can enable the development of a new generation of general aviation aircraft. Specifically, Cockpit/Airspace/Airplane Technologies have matured in 1980's and which will mature in the 1990's, enable the potential for an expansion in the utility, safety, and use of general aviation airplanes in the U.S. air transportation system

COCKPIT 2000

- Ease in Learning/Relearning

- Autonomous Operations



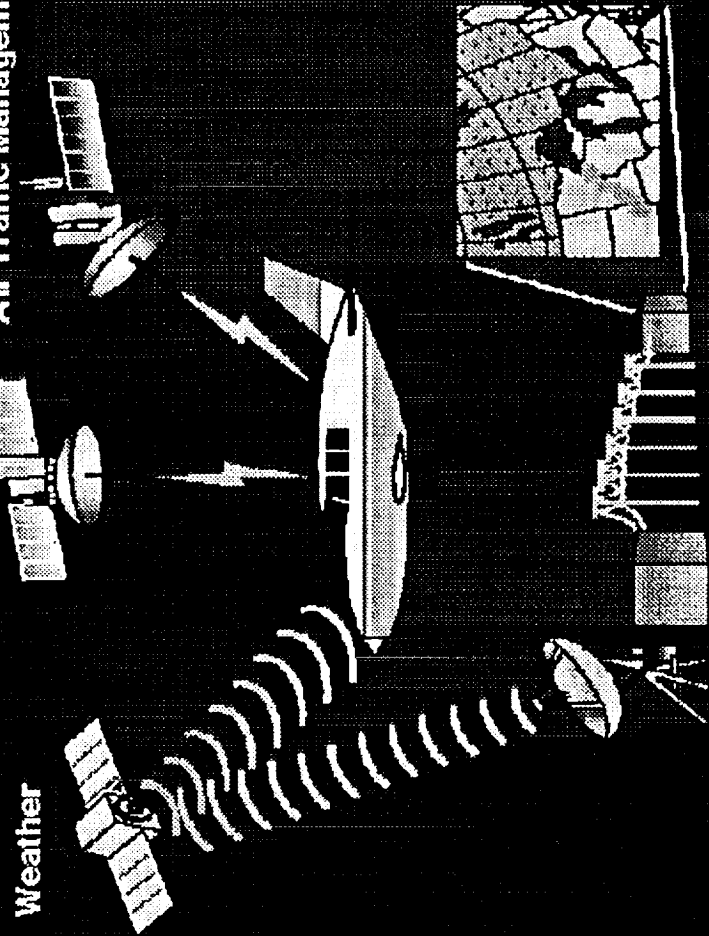
- Intuitive Controls / Displays

Cockpit 2000

The development of low cost, small computers and flat panel displays have created the opportunity to apply human-centered automation technologies which can enable the development of systems for controls, navigation, communication, and operations which are easier to learn and relearn, and systems which can provide for computer aided decision-making for simplified operations in future aircraft. These systems can also have embedded instruction capabilities; in fact, the cockpits in these future aircraft could have dual use as simulators on the ground for training purposes.

AIRSPACE 2000

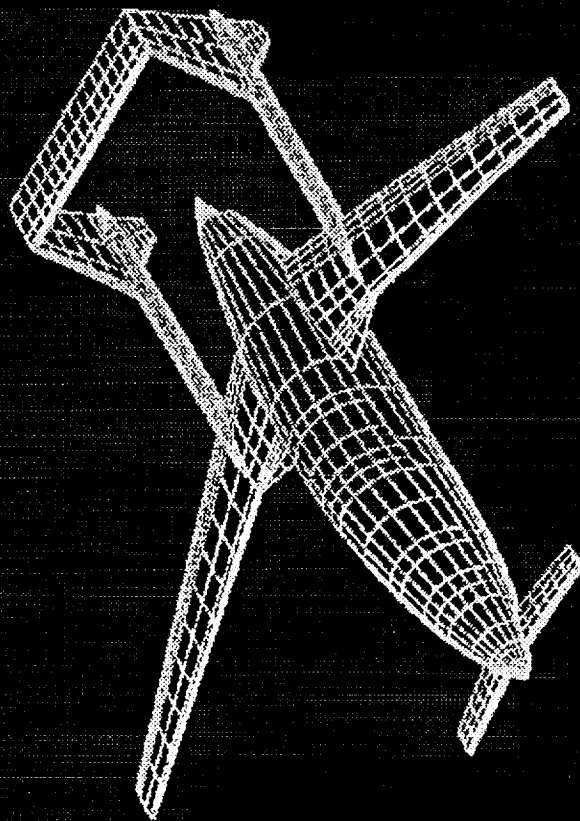
Navigation Satellite Systems
Air Traffic Management



Airspace 2000

- Within the past several years we have seen a **migration** of weather information centers out of the **flight service** weather bureau stations into briefing rooms at local airports. The next logical step in the migration is for weather information to be provided in the **cockpit**. In fact such a system was test flown in a Piper Malibu under a NASA SBIR research contract in the Summer of 1990, in Wisconsin. With today's communications and sensor capabilities, it is even possible have general aviation airplanes report meteorological data to other aircraft and ground stations, much the way the transport operators have started doing today.
- The development of **GPS** and other global navigation satellite systems is the most significant revolution since the **advent of radio navigation**. This technology will provide the **accuracy** to make every landing sight at least a Category I Precision Approach. The accuracy is only half the story, the **cost** is the other half. As the use of GPS navigators spreads throughout the world for both air and ground vehicles, economies of scale will drive costs down.
- The final part of the Airspace story is the future air traffic management system. The FAA has been provided with \$32 billion **Capital Investment Plan** to modernize the navigation, communication, surveillance, and control systems for our nation's next generation airspace system. This system has the potential to support the General Aviation Vision and strategy in this presentation.

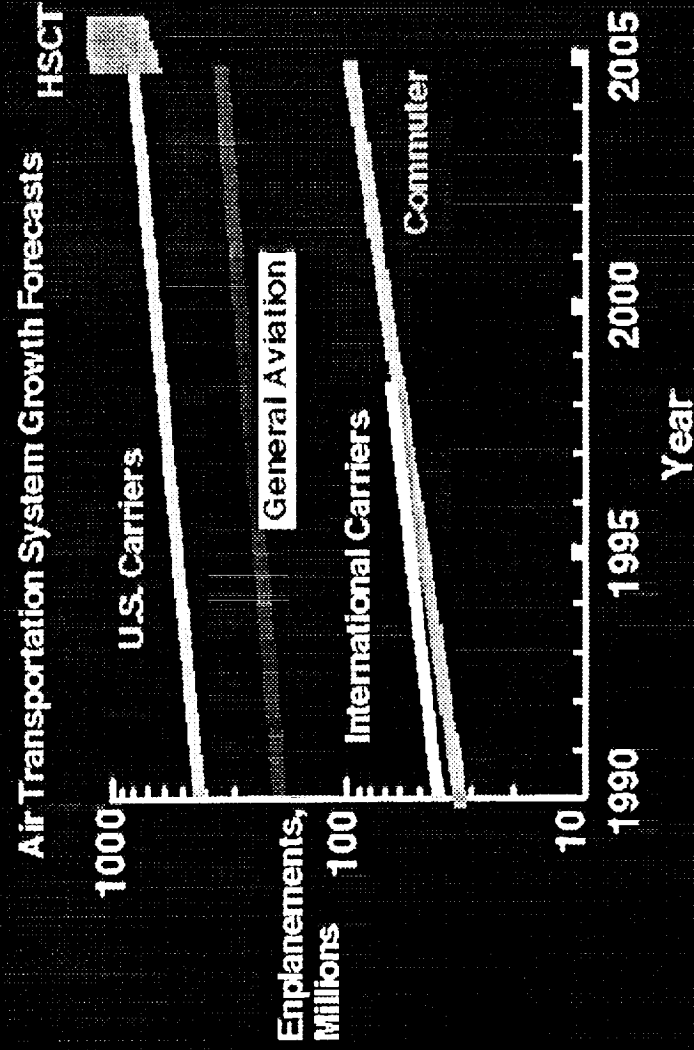
AIRPLANE 2000 (Roskam, et.al., 1990)



Airplane 2000

- In order for the next generation of general aviation airplanes to be environmentally and economically acceptable, they need to take the fullest possible advantage of advancements in
 - acoustics,
 - materials and manufacturing methods,
 - aerodynamics,
 - and propulsion.
- As the world's aircraft companies have learned to squeeze every last drop of performance out of airplane designs, the competition has moved from performance to product development cycle times. This means that significant competitive advantage is gained by investing in the development of advanced computational design tools, improved testing techniques, and lower cost manufacturing technologies.
- These advancements need to be incorporated in order to "pay the way," so to speak, for the investment in the cockpit technologies which expand the utility and safety.

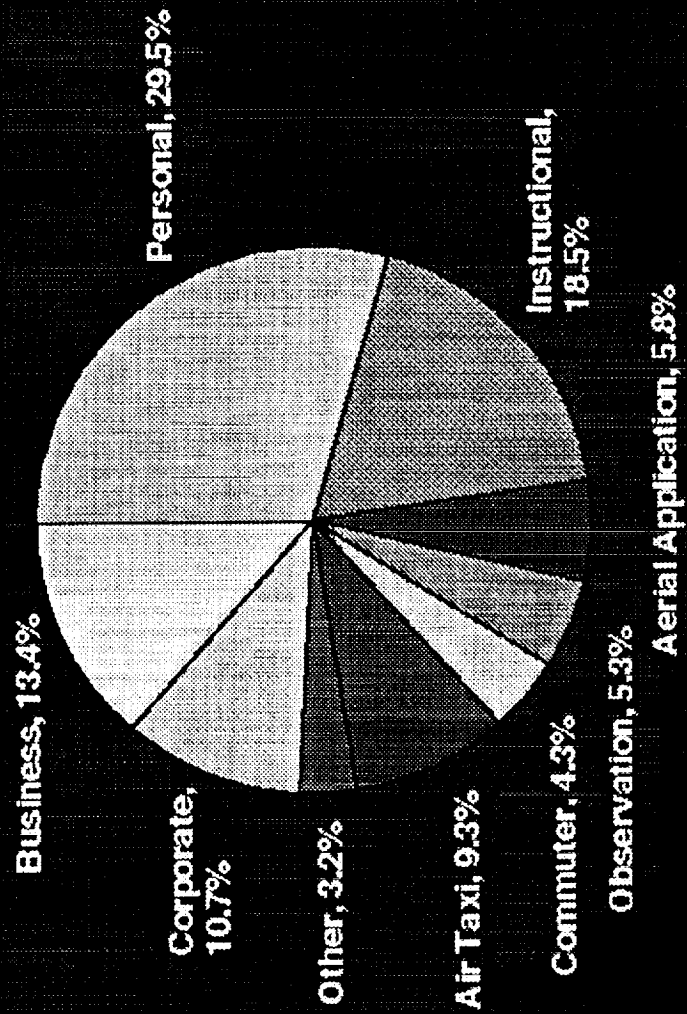
MARKET DEMAND



Market Demand

- General Aviation enplanements = 1/3 of U.S. Air Carriers, 3 times commuter & Int'l Carriers
General Aviation **miles flown** (4.5578 billion) = Air Carrier (4.9478 billion miles)
 - In terms of enplanements, General Aviation is the **nation's largest airline!**
 - important to look at P-Ms for 150 to 700 mile trips:
 - GA is 1/3 of those air trips, 4% of total air and ground
 - for shorter trips, <150 m., cars serve most of need
 - for longer trips, >700 m., long haul scheduled air carriers serve most of need
 - General Aviation could expand to fulfill more of the nation's need for the intermediate routes.
- **What's wrong** with this picture is that the **growth rate** forecast for general aviation is only 0.3%, or one-tenth of the growth rate of a healthy GDP growth rate. In comparison, the other modes of air travel are forecast to grow at rates of 4 to 7 percent.
- From the perspective of **people served**, G.A. is a large part of the national air transportation system, is underutilized, and can contribute in our efforts to improve airspace capacity and congestion.

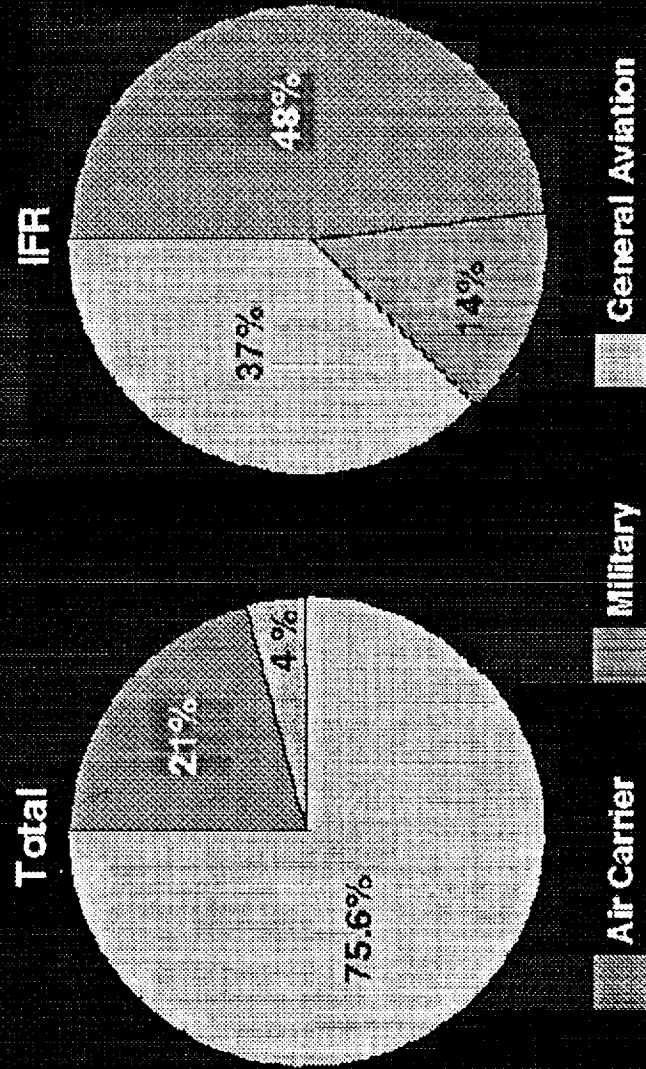
GENERAL AVIATION AIRCRAFT USE 1989
TOTAL = 35,012,000 HOURS



General Aviation Aircraft Use

- G.A. flew 35M hours in 1989, twice the Air Carrier hours; 62% for cross-country
- 30% Personal Flying is the GA equivalent of tourist flying on the airlines (54% of Air Carrier flying is "personal"). Even the 30% personal use is important to the economic health of FBO's so that they will be able to serve the commercial users (47% of nation's FBO's lost money last year)
- By the measure of **value of usage**, technology development for expanded use of General Aviation would be a wise investment for the future U.S. Air Transportation System infrastructure

U.S. ANNUAL AIR TRAFFIC OPERATIONS 1987-1989 AVERAGE



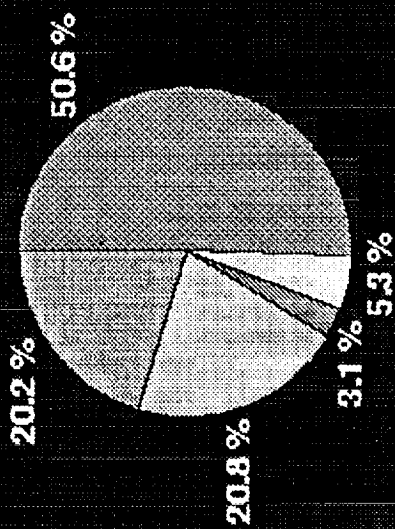
U.S. Total Annual Air Traffic Operations, 1987-1989 Average

- An operation is an arrival or a departure.
- Total U.S. operations comprised of 75% G.A. aircraft;
G.A. departures are nearly 4 times the rate of Air Carriers
- There are important **differences** between the two kinds of pilots and operations.
GA pilots tend to be part time, fly into **strange airports** more frequently than scheduled air carrier pilots, have less time to invest in **initial and recurrency training**, and have less capable **equipment** both in terms of aircraft and systems performance, and in cockpit flight systems.
- For maximum impact, research to improve the **operational capacity** of the national air transportation system should address the **cockpit and airspace** technologies specific to G.A. airplanes and pilots in addition to our current efforts for transport aircraft.

GENERAL AVIATION FATAL ACCIDENTS 1982-1988

Human Factors

By Cause



Terminal (Weather, Stall/Spin, Other)

Power/Propeller/Systems

Fuel Management

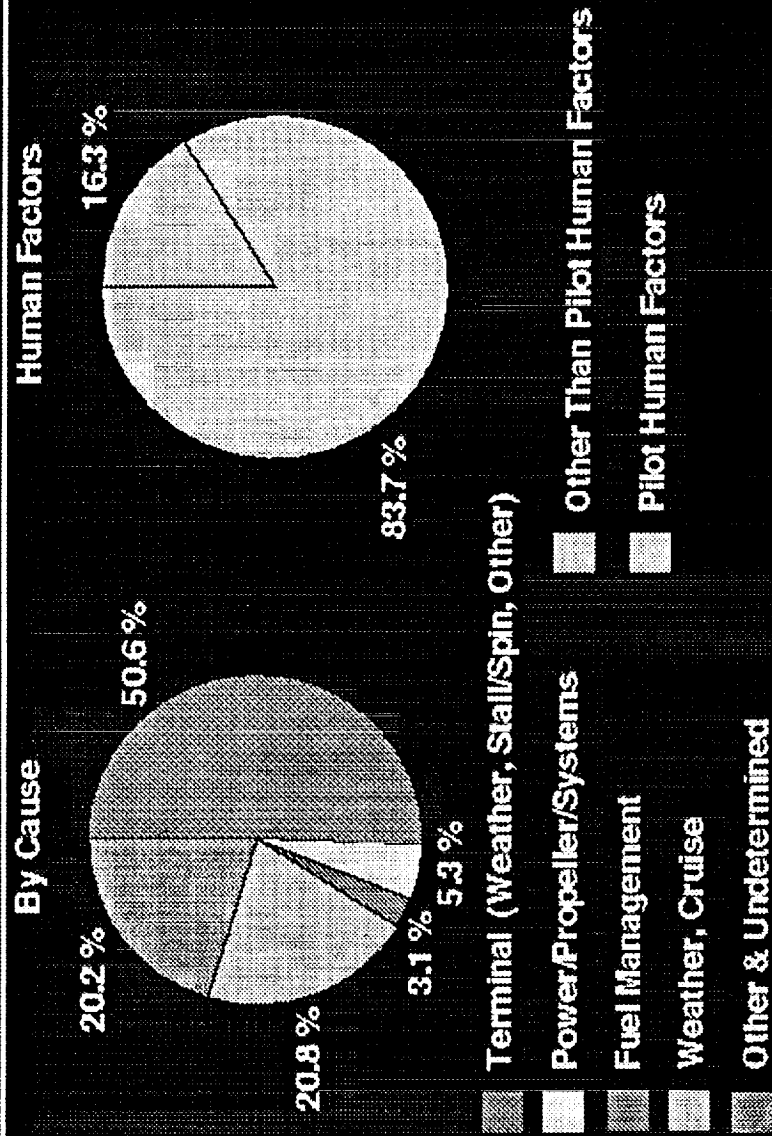
Weather, Cruise

Other & Undetermined

General Aviation Accidents (1982-1988, AOPA/ASF)

- Enormous improvements over the past decades for G.A. accidents; **current fatalities/100 Khrs is 1/2 of 1975 rate;**
 During past 4 years, G.A. acft flown by salaried crews had fewer
 accidents/100Khrs than scheduled air carriers
- The message in these accident statistics is that newly maturing technologies can significantly impact nearly all of the kinds of accidents occurring today.
- The general aviation safety **goal** should be established by studying the reasons for the outstanding record for corporate aviation safety, understand the differences between the pilots, equipment, and operations, then apply the lessons to all of general aviation.
- Terminal operations accidents include taxi, takeoff, climb, descent, IFR and VFR approach, and landing. The casual factors in these accidents include stall/spin or other loss of control, attempted VFR into IFR conditions, improper operations, and mid-air collisions (which represent 0.5% of all accidents).
- Cruise weather accidents are 4.7% of total, but 20.8% of fatal accidents. New technologies are particularly relevant to this kind of accident. If pilots can be aware on a near real time basis of their position, the relative location of weather and terrain, this kind of accident would greatly decrease. We have most of these technologies ready for integration today. The challenges are human factors engineering of the displays, and certification.

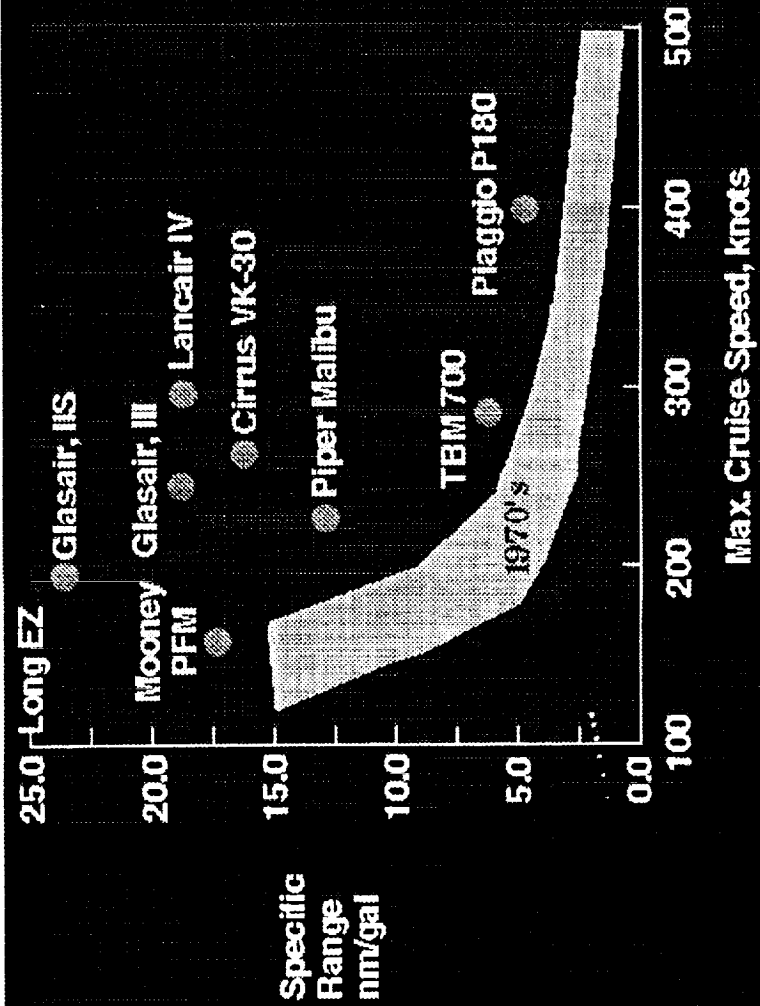
GENERAL AVIATION FATAL ACCIDENTS 1982-1988



General Aviation Human Factors Accidents (1982 - 1988)

- Overwhelming proportion: Human Factors
 - Involving flight deck; ATC-flight deck interactions; aircraft maintenance; and airways maintenance
- The airframe/engine/systems play a decreasing role in accidents.
- Definition of "Human Factors" related accidents
 - Judgment
 - Man-machine interface
 - Need to include other than "Pilot-Error" in this category, Numerous casual factors include:
 - improper maintenance
 - improper installation
 - improper overhaul
 - improper part
 - improper assembly
- Technology offers to greatly alleviate many "Human Factors" accidents
- We need to expand General Aviation activities in the National Human Factors Research Program

FUEL EFFICIENCY COMPARISONS



Fuel Efficiency Comparisons

- This figure illustrates the **strides** of the past two decades in airplane performance. We have seen a doubling of the fuel efficiency at a given speed; conversely, we have seen a doubling of the speed at a given fuel efficiency.
- While these gains are impressive, even **further gains** are possible from advancements in:
 - Drag reduction aerodynamics, including laminar flow control
 - Lighter weight structures and materials
 - Improved engines with lower power-to-weight ratios and fuel burn
- As the world's airplane manufacturers continue to take advantage of these advancements, a new driver for competition is emerging: **product development cycle time**. The ability of U.S. manufacturers to compete in the future will increasingly depend on their ability to reduce the time required to design, test, and certify new aircraft and systems. Aeronautics research can contribute to reduced cycle times by improving the speed and accuracy of computational design tools, testing techniques, and certification processes.

OBSTACLES TO UTILITY

USER ACCEPTANCE

- Cost/Performance
- Time for learning/relearning
- Safety
- Comfort

Obstacles to Utility

- The **critical question** is, "What obstacles inhibit the expanded use of General Aviation aircraft?" This is an important question because the **solutions** lie in the answers.
- Cost of ownership / operation / nearly all-weather systems performance
 - Product liability adds to the purchase price
 - Current production rates of 1500 aircraft do not command economy of scale
 - Tax laws, Airline competition, Reliability
 - Both **technology and volume** are required to bring costs down.
- Proficiency requirements
 - Learning and re-learning to fly airplanes requires expensive time/cost
 - Airplanes must be made **easier** to learn and re-learn how to fly
- General Aviation fleet safety is not yet competitive with automobiles
 - The goal for G.A. should be to achieve corporate levels of safety; It will be difficult to achieve, but **technology** offers significant help.
- Ride comfort
 - Gust response
 - Interior noise: without headphones;
 - Features: air-conditioning; audio systems; flight phones.

OBSTACLES TO UTILITY

USER ACCEPTANCE

- Cost/Performance
- Time for learning/relearning
- Safety
- Comfort

COMMUNITY ACCEPTANCE

- Noise
- Safety
- Emissions
- Elitist Image

Utilization Inhibitors. (Concluded)

- Airport noise concerns top the list. The threat of **curtailed, curfewed, and outright banning** of aircraft operations at many of the world's airports is increasing.
 - Advanced **acoustics technologies** have improved our ability to deal with these threats.
- Until **safety** improves for the entire General Aviation fleet, the community acceptance for this mode of travel will remain low.
 - The safety goals previously discussed can be sought after through the application of **cockpit information and display technologies**.
- **Emissions** are becoming an increasing concern as subsonic fleet sizes increase.
 - From a technology standpoint, we need to look at the application of advanced electronic engine **controls** and alternative engine **cycles** and fuels on future fleet emissions.
- The elitist **image** which many in the public have for General Aviation is a result of the fact that a relatively small part of the population makes direct use of this mode of travel. As an increasing part of the population comes to experience the benefits of General Aviation, either **directly, or indirectly**, this image should change.

PROGRESS IN TECHNOLOGY

Non - Aeronautical

- airbags
- anti-lock brakes (in 1.7 million 1992 cars)
- CD-ROM
- cellular telephone
- cruise control
- electronic ignition
- electronic moving maps
- infrared remote controls
- interior noise control
- displays
- micro computers
- radial tires
- reliable powered subsystems
- smart "idiot" lights
- smart suspension system

Progress in Technology

- Since the last applications of significant technical advancements in G.A., numerous technologies have become a part of **everyday life** in mass markets and presumably could contribute to the development of new airplanes.
- These non-aeronautical technologies have established the **level of expectation** of the marketplace for future airplanes which would be marketed to travelers beyond the historical "enthusiast" market.

PROGRESS IN TECHNOLOGY

Aeronautical

- ACARS
- Active Noise Control
- Advanced Metallics
- CAD/CAM
- Computational Fluid Dynamics (CFD)
- Fault-tolerance
- Fiber-optics
- Lightning Protected Composites
- Crash-worthiness
- Computational Structural Mechanics (CSM)
- Enhanced Visual Systems (EVS)
- GPS
- LORAN
- NLF/HLFC
- Molded Phenolic Composite Engines

Progress in Technology. (Concluded)

- During the **past decade** aeronautics technologies have advanced significantly.
- Many of these technologies have been incorporated into the modern fleet of **business jet and turboprop aircraft** built and selling in the U.S. today. However, these technologies have not been incorporated into the smaller aircraft which have **less and less of the utility needed** for safe, comfortable, economical operation in today's increasingly complex airspace system.

FUTURE TECHNOLOGY DRIVERS

Advanced Airspace System
GPS
ATC
Data Link

Real Time

Cockpit

Weather

Direct

Broadcast

Satellites

Advanced

Engines

Satellite Based

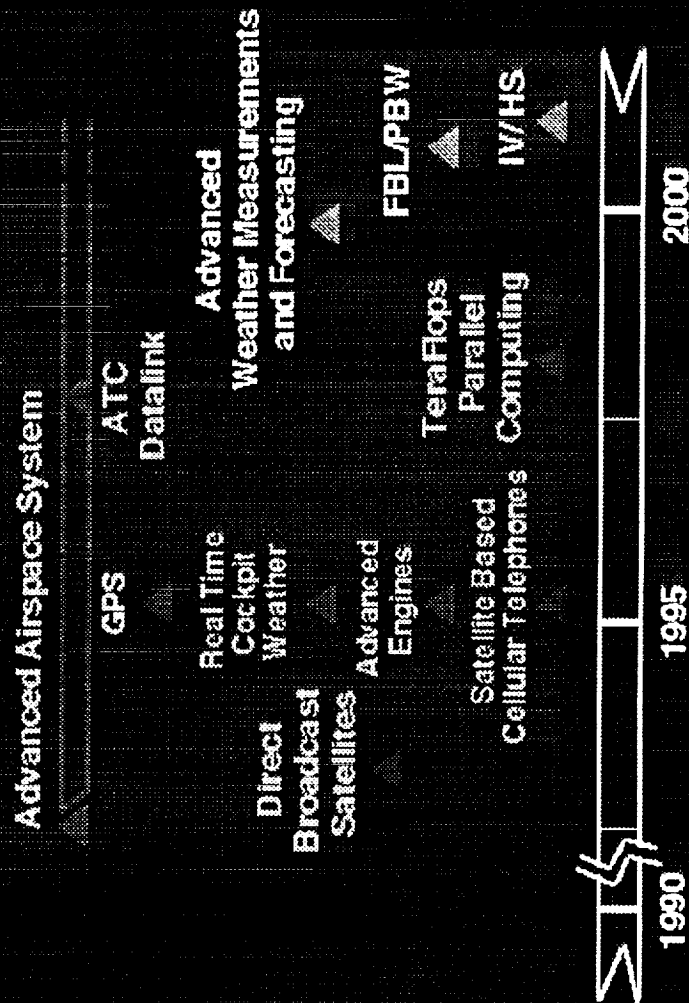
Cellular Telephones



Future Technology Drivers

- Direct broadcast satellites may be commercially operationally before 1994 to carry both voice and video information
- The first GPS precision approach is planned to be operational this summer for the Experimental Aircraft Association convention in Oshkosh, Wisconsin.
- Near real-time weather products in the cockpit could be available on a subscription basis by 1995.
- Advanced engine activities which are underway at NASA could result in a rotary engine flight evaluation in the 1995 time frame.
- The advent of satellite based cellular telephones could add a new dimension of creature comfort and convenience to all air transportation.
- The U.S. \$32 billion investment in the FAA Advanced Airspace System has the potential to support the next generation general aviation transportation safety, utility, and expansion goals. ATC Datalink, as part of the communications system improvements, could be on line before 1998).

FUTURE TECHNOLOGY DRIVERS



Future Technology Drivers (cont'd)

- TerraFlops computing will increase speed 1000-fold and decrease cost of high-performance computing.
- Fly-by Light/Power-by-wire will come into maturity in the next decade
- Intelligent Vehicle/ Highway System may provide for crucial economies of scale for GPS components and flat panels when produced at the level of millions of units/year for automobiles.
- Advanced Weather Measurements
 - ASOS: (NWS, 537 units, 1992 - 1996)
 - AWOS: (FAA, 40 units, 1992 - 1993)
 - NEXRAD: (NWS, 113 sites, 1993 - 1996?)
 - TDWR (FAA, 47 sites, 1993 - 1995)
 - Profilers (NWS: Block 1, mid U.S. today
Block 2, 200-300 units nationwide about 2000 a.d.)
 - MAPS (NCAR/NWS, Aviation Gridded Forecast System, 1998)

FINDINGS

- ♦ General aviation situation:
 - Major segment of the national air transportation system
 - Threatened
 - Potential for expansion in safety, utility, performance, use
- ♦ Potential for expansion enabled by new technologies:
 - Navigation
 - Communications
 - Controls
 - Information systems
- ♦ Environmental and economic acceptability enabled by technical advancements:
 - Aerodynamics
 - Acoustics
 - Propulsion
 - Materials
- ♦ General Aviation mission requirements are under-represented in national technology strategies.
- ♦ U.S. research planning cannot wait for product liability resolution.

Findings

- General Aviation's capability to serve the U.S. transportation needs is **threatened**, but GA can be **revitalized** with vastly greater safety, capacity, utility and efficiency to contribute fully to U.S. economic growth.
- Newly maturing technologies have laid the **foundations** for general aviation to expand, not only to meet **U.S. needs**, but to meet **foreign market** needs (especially third world) as well.
- As international aeronautical **competition** has squeezed nearly ever last mile-per-gallon out of technologies, the **competitive playing field** of the future will be dominated by who can move the fastest through **product development cycles**. This means that to be competitive, the U.S. must invest in the development of technologies affecting faster, more accurate **computational design tools**, advanced **testing** techniques, lower cost, faster **manufacturing** techniques, and more rapid **certification** processes.
- The primary task of the NASA Advisory Council, Aeronautics Advisory Committee, **Task Force** on General Aviation Transportation is to address the last point concerning a national technology strategy to define what technologies are needed to enable general aviation to contribute to the national airspace **capacity** issues and **revitalize** the U.S. general aviation industry through expanded use and volume of production. While product liability is still critical, research planning must begin now.

GENERAL AVIATION GOALS

- Safe, high utility airplanes
- Electronic VFR
- Decision-Aided Flight Planning and Operations
- Electronic Cockpit Libraries
- Dual-Use Cockpits
- Environmentally, economically acceptable airplanes:
 - Acoustics
 - Propulsion
 - Materials and Manufacturing Methods
 - Aerodynamics

GA Goals

- The General Aviation Safety goals could be established by translating the lessons from the ultra-safe corporate operations, where feasible, to the General Aviation fleet.
- Electronic VFR: means minimize the IFR/VFR distinction
 - Wide field of view displays
 - Single, GPS-based universal approach procedures and systems
 - Near real-time weather in the cockpit
- Decision-Aided Flight Planning and Operations
 - increased autonomy, transparent to operator
 - Integrated weather, traffic information in the cockpit for preflight, enroute operations
 - GPS-based random access, point-to-point navigation
- Electronic Cockpit Libraries
 - Optical storage of enroute and terminal navigation information
 - Datalink for comm and clearance information
 - Electronically stored and displayed aircraft performance data

Technology Goals (concluded)

- Dual-Use Cockpits
 - Embedded Flight Training (recurrent and, ultimately, initial)
 - Intuitive (decoupled) flight controls and displays
 - Flight envelope protection systems
 - Self-teaching simulators and onboard flight systems
- Aircraft for expanded general aviation utility must meet community environmental expectations, and user expectations for utility and cost.

NATIONAL TECHNOLOGY STRATEGY PROPOSAL

- Establish viability of General Aviation expansion.
- Establish public constituency in support of expanded General Aviation utility and use.
- Integrate research with aircraft & airman certification processes for new technologies.
- Coordinate cockpit & airplane technology planning with FAA Capital Investment Plan.
- Strengthen avenues for technology transfer to U.S. industry.

Technology Strategy

- Establish viability of a new transportation mode:
 - Environmental
 - Economic
 - Technical
 - Political and social
- Establish public constituency in support of a new air transportation mode
 - In "off-airways" communities throughout the nation
 - G.A. is today where the automobile was in the 1930's before the Interstate Highway System
 - Educate public about the future G.A. role
- Integrate research with certification processes for new technologies.
 - Predictable cost to certify
 - Predictable time to certify
 - Use of simulation for advanced flight systems certification (systems reliability, compatibility, interoperability)
- Work to assure that the capabilities in the Automated Airspace System will fully enable and support this general aviation vision.

Technology Strategy (continued)

- Capitalize on new capabilities for technology development and transfer involving cooperative-proprietary government/industry efforts
 - New ways for Industry/Government to collaborate for **competitiveness**
 - Strengthen weak link in the technology development chain: **validation**
 - NASA / FAA/ Universities/**SBIR**

